E4S & Resilio White Paper

Environmental impacts of the ICT sector in Switzerland

White Paper

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 Enterprise for Society (E4S) is a joint venture of the University of Lausanne through its Faculty of Business and Economics (UNIL-HEC), the Institute for Management Development (IMD) and the Ecole Polytechnique Fédérale de Lausanne (EPFL), under the stewardship of its College of Management of Technology, with the mission of spearheading the transition towards a more resilient, sustainable, and inclusive economy. E4S is committed to training the next generation of leaders, inspiring economic and social transformation, and promoting change by strengthening start-ups and boosting innovation.

Resilio supports organisations in reducing the environmental footprint of their digital infrastructures or services. It is a private company that, rather than pursuing profit maximization, is driven by a desire to make a difference by creating significant positive impacts. Resilio has developed a unique set of tools & methods enabling easier, faster and more accurate Life Cycle Assessment (LCA) of Information and Communication Technologies (ICT) with up-to-date data. The Lab team is dedicated to pushing the boundaries of knowledge in the field. It is carrying research including this study.

The full study report and more information can be found at sustainableit.ch

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Executive Summary

The role of human activities in environmental crises is now undeniable. In 2016 Switzerland signed the Paris Agreement along with 196 nations[1] and continued to set other **ambitious targets**.

Digital technology plays a complex role in environmental matters. While it seems immaterial, it notably contributes to **pollution and resource depletion**. It is crucial to assess and mitigate its environmental impacts to ensure a more sustainable future.

To answer this need, many Swiss organisations and institutions conducted a study on **Information and Communication Technologies (ICT)** in **Switzerland** aiming to :

- **Identify** the main sources of impacts;
- **Inform** policy-makers and motivate them to **take action**;
- Contribute to **raising awareness** among Swiss citizens and businesses.

The study's methodology is based on **Life Cycle Assessment** (LCA), used to assess the environmental impacts of a system through the life cycle and considering many environmental impacts. The perimeter studied is the entirety of **digital equipment and infrastructures** in use in Switzerland, for **personal and professional use**, in **2024 and projections in 2035**.

The key results from this study show that ICT infrastructures contribute to **2% of the total Swiss consumption-based CO_2 emissions** and **12% of total electricity** consumption in 2024. Furthermore, the **footprint will increase rapidly until 2035**. These trends are due to the increase of the population and the growth of new usages (generative AI, virtual reality, etc.). **Metals and minerals resource use** plays a critical role. There is a specific concern about the **rising demand for electronics**.

End-user equipment is the main driver of environmental impacts in 2024. However, the trends until 2035 will reverse as data centres and networks footprints will strongly increase and concentrate **most of the impacts by 2035**.

It is essential to act upon these conclusions to **ensure the sustainability of the digital transformation**. The recommendations presented in this study are structured around three objectives:

1. **Decrease the need for new devices manufacturing**: avoiding manufacturing new equipment whenever it is possible by extending the lifespan of devices;
2. **Design and manufacture more efficient equipment and infrastructures**: manufacture less resource-intensive devices, by practising sobriety and circularity;
3. **Arbitrate digital use**: critically assess and moderate the use of digital technologies to ensure they meet genuine needs without excess.

[1] https://unfccc.int/process-and-meetings/the-paris-agreement

1. Introduction

The role of human activities in environmental crises is now undeniable, as stated in the sixth assessment report of the Intergovernmental Panel for Climate Change[2]. The expansion of industries, urbanization, and deforestation is altering ecosystems, threatening countless species and disrupting the delicate balance of nature. Pollution, excessive resource consumption, and climate change further accelerate this decline, **reducing the planet's ability to regenerate itself**.

The Paris Agreement signed in 2016, endorsed by 196 nations including Switzerland, aim to limit global warming to well below 2°C above pre-industrial levels, with efforts to cap the increase at 1.5°C[3]. Despite record growth in renewable energies installations in Switzerland[4], **current projections indicate a significant shortfall[5] in meeting this target**. **Significant efforts are essential to bridge this gap** and fulfil the Paris Agreement objectives.

In this context, **digital technology plays a complex role**. While it may seem immaterial at first glance, it is deeply rooted in reality. The extraction of raw materials, energy-intensive data centres, and the growing volume of electronic wastes contribute to many pollutions and resource depletion. It was estimated in 2015 in Switzerland that digital technologies account for about 3% of the total greenhouse gas emissions of the country[6].

While these technologies can offer solutions for environmental monitoring and energy efficiency, they also have a **significant ecological footprint** which cannot be overlooked. As the use of digital technologies continues to increase, it is essential **to assess and mitigate their environmental impacts** to ensure a more sustainable future.

To answer this need, Resilio, in collaboration with many institutions such as the International Telecommunication Union (ITU), Swiss Federal Institute of Technology in Lausanne (EPFL) and many more, has decided to **conduct a study** aiming **to evaluate the environmental impacts of digital technologies in Switzerland in 2024 and 2035**.

The intended audience of this study is the following:

- Swiss citizens;
- Swiss policymakers;
- Digital industry leaders.

[2] AR6, IPCC, 2021, https://www.ipcc.ch/assessmentreport/ar6/
[3] Paris Agreement, United Nation, 2015, https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[4] Switzerland installs 1.78 GW of PV in 2024, PV magazine, https://www.pv-magazine.com/2025/01/27/switzerland-installs-1-78-gw-of-pv-in-2024/
[5] "Les mesures adoptées par la Suisse sont insuffisantes pour limiter le réchauffement climatique", actu-environnement.com, https://www.actu-environnement.com/ae/news/comite-ministres-decision-mesures-suisse-insuffisantes-limiter-rechauffement-climatique-45744.php4
[6] Hilty, Bieser, 2017, Opportunities and risks of digitalisation for climate protection in Switzerland. University of Zurich, Swisscom, WWF https://www.ifi.uzh.ch/dam/jcr:066776d8-d2b0-4c7c-b75d-6b7283cb5791/Study_Digitalization_Climate_Protection_Oct2017.pdf

2. Methodology

The goal of the study is to provide the latest knowledge about the **environmental impacts** of the **digital sector in Switzerland**. To do so, this study focuses on the **devices and infrastructures related to digital technologies** used in and from Switzerland in 2024 and as they are expected to evolve by 2035.

2.1 Method and framework

This study is based on Life Cycle Assessment (LCA) methodology, which consists in evaluating the potential environmental impacts of a product or service. LCA's key characteristics are the following:

- A **multi-criteria approach**: Several environmental indicators are included in the analysis: global warming potential, depletion of abiotic resources, water, air and soil pollution, etc.
- A **life-cycle perspective**: Considering the environmental impacts of all life cycle stages of a system's life cycle, from raw material extraction to production, use, and disposal. It is illustrated in Figure 1.

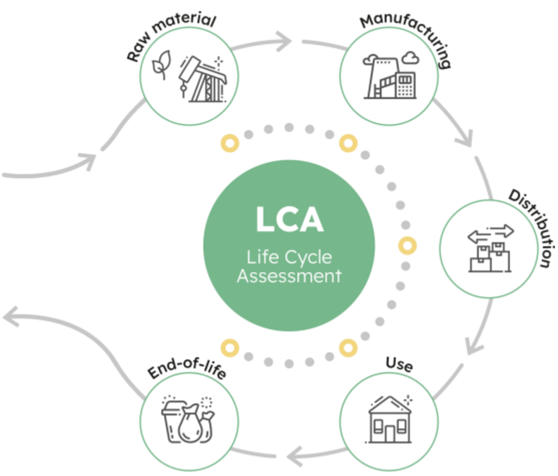

Figure 1- Diagram of life cycle stages usually considered in LCA

There are two types of LCAs:

- **Attributional**: Describes the direct environmental impacts associated with a product or service in its current state
- **Consequential**: Assesses the environmental consequences of a change in the system (e.g. policy change, variation in demand, innovation).

In this study, a **simplified attributional LCA** was performed (at the devices level), focusing on **direct impacts only**. The simplified method is preferred, considering the scope and the quality requirements of the project.

2.2 Functional unit

The **functional unit** of a product or a system is a quantified description of its performances, serving as the reference point for all environmental impact calculations. It is quite difficult to classify the use of digital technologies in different functional units, due to the multiplicity and diversity of uses. Therefore, the functional unit is replaced by two declared units, one on a global scale:

"Equipment and infrastructures related to digital technologies used in Switzerland over a year".

And on an individual scale:

*"Equipment and infrastructures related to digital technologies used in Switzerland over a year **per inhabitant**".*

2.3 Scope

The perimeter of this study covers three different categories of equipment called "Tiers" which can be classified into the following:

1. **Tier I - End-user equipment**: All equipment directly used by final users. It includes devices such as smartphones, laptops, monitors or connected objects. Tier I is separated into two categories:
    - **Tier I for personal usage**: equipment bought and used directly by the user, for their own personal use;
    - **Tier I for professional usage**: equipment bought or lent by a company, used by the employees in a professional context.
2. **Tier II - Telecommunication networks**: This category includes the infrastructures responsible for data transmission between the end-users and the data centres. It is composed of a fixed network, a mobile, and a backbone one;
3. **Tier III - Data centres**: This category encompasses all devices dedicated to the hosting and treatment of data (servers, routers, cooling equipment, etc.).

Considering the **geographical** scope, all equipment geographically installed and used in Switzerland are evaluated and accounted for. Special attention is given to Tier III, data centres. Indeed, on one hand, some facilities located in Switzerland provide cloud services to users abroad and are thus excluded from the scope. On the other hand, the portion of the cloud services consumed by users in Switzerland, hosted in data centres located outside the country is included in the assessment. This approach aims to provide the most accurate estimate of the environmental impacts attributable to the Swiss population.

Two **temporal perimeters** are chosen for this study:

- 2024: to assess the current environmental footprint of ICT in Switzerland,
- 2035: to estimate future impacts, through a prospective scenario.

Given that each temporal scope covers a one-year duration, the environmental impacts of devices with lifespans longer than one year are **amortized on an annual basis** (i.e., their total life cycle impacts are divided by their respective lifespans).

More details about the methodology are given in the study report.

2.4 Approach

The next step of an LCA, after defining the scope and functional unit, is to compile the life cycle inventory. In this study, this consisted in collecting data on ICT devices in Switzerland. The data collected are as follows:

- **Number of equipment** of each category (smartphones, servers, 4G antennas, etc.);
- Unitary **electricity consumption**;
- **Lifespan.**

The data related to the **life cycle impacts of ICT equipment** or flows entering the studied system is mostly obtained from two databases: Resilio Database[7] and NegaOctet[8].

Concerning the prospective scenario, the main hypotheses made are the following:

- **Tier I**: The quantities of end-user devices are estimated considering the projected population increase;
- **Tier II**: The quantities and electricity consumption of networks model is based on the expected increase in subscribers and data transferred;
- **Tier III**: The electrical consumption increase is based on prospective scenarios, and the amount of equipment of data centres is changed accordingly.

2.5 Environmental impact categories, data and tools

This analysis is based on the 16 environmental indicators proposed by the European Commission within the framework of the Product Environmental Footprint (PEF) project, using **PEF 3.0** version.

To make the results as understandable as possible and to focus on key issues, the full set of indicators is reduced to the most significant impact categories, presented in Table 1.

The computation is done using **ResilioTech**[9], a software developed by Resilio to perform LCAs of digital services.

The critical review is not compliant to ISO or other norm; it is performed by external reviewers as mentioned at the beginning of the document.

Table 1 - List of selected impact categories

Impact category	Acronym (unit)	Definition
Resource use, minerals and metals	ADPe (kg Sb eq.)	Potential environmental impact associated with the extraction and use non-renewable mineral and metal resources, which are extracted from the Earth's crust considering their scarcity and economic importance
Ecotoxicity, freshwater	CTUe (CTUe)	Potential toxic effects of chemical emissions, on freshwater ecosystems (rivers, lakes, etc.), specifically their toxicity on aquatic organisms over time
Climate change	GWP (kg CO_2 eq.)	Contribution of greenhouse gas (GHG) emissions, to global warming over 100 years.
Resource use, fossils	ADPf (MJ)	Reflects the long-term reduction in the availability of non-renewable fossil energy resources due to their extraction and use
Particulate matter	PM (disease incidence)	Potential human health impacts caused by the emission of particulate matter (PM) and its precursors.
Eutrophication, freshwater	Epf (kg P eq.)	Contribution to the eutrophication of freshwater systems, caused by the excess loading of nutrients, mainly nitrogen (N) and phosphorus (P).

[7] https://db.resilio.tech/

[8] https://codde.fr/nos-marques/negaoctet/base-de-donnees

[9] https://resilio-solutions.com/fr/services/tech

3. Results

In this section, environmental footprint results for year 2024 are presented, starting from a global overview and moving toward more granular analyses and the environmental footprint projection results for 2035 are shown.

3.1 Global evaluation

3.1.1 Digital technologies in Switzerland in 2024

Internet users

As of the 2nd trimester 2024, Switzerland's population is estimated at 9,002,763 individuals[10]. Among this population, 99% are active internet users spending an average of 5 hours and 32 minutes per day on the internet[11], reflecting the nation's extensive digital connectivity.

As of December 2024, the number of employed individuals in Switzerland is reported at approximately 5,521,429 individuals, according to data from CEIC Data[12].

Devices and infrastructures

Considering all three tiers of the digital ecosystem (end-user devices, data centres and networks, excluding industrial IoT) the total number of ICT devices in use in Switzerland in 2024 is estimated at **73,473,459 units**. This corresponds to an average of **8.5 devices per inhabitant**.

Of this total, approximately 94% are end-user devices, 5.6% are data centre equipment, and only 0.4% are attributed to telecommunications network infrastructure. The number of telecom infrastructure devices is naturally lower than that of end-user equipment because infrastructure is shared across a large number of users. This mutualization leads to a lower device count relative to the population served.

Switzerland's total electricity consumption is approximately 57 TWh[13], with **digital technologies collectively consuming around 6.9 TWh**. This represents nearly **12% of the country's overall electricity use**, reflecting the significant demand from the digital sector.

Data centres alone account for a substantial share of this consumption (almost 50%), estimated at about 6.1% of total Switzerland's electricity consumption. Indeed, Switzerland has a high density of data centres per capita. This attractiveness can be explained by strict data protection, the country's political stability, its low-carbon electricity mix, and low environmental risks (e.g. seismic activity).

[10] https://www.bfs.admin.ch/news/fr/2024-0538
[11] Internet users aged 16 to 64, https://datareportal.com/reports/digital-2024-switzerland
[12] https://www.ceicdata.com/en/indicator/switzerland/employed-persons
[13] https://www.news.admin.ch/en/newnsb/iTP15U0PYP57z2h_7EXJO

3.1.2 Environmental impacts at the scale of the country

Global environmental footprint results of ICT technologies in Switzerland in 2024 are presented below.

Resource use, minerals and metals (ADPe)
186 t Sb eq.

Climate Change (GWP)
1,99 million tons of CO_2 eq.

Ecotoxicity, freshwater (CTUe)
65,038,535,926 CTUe

The impact on metal and mineral resource use (ADPe) corresponds to 40% of the total footprint and represents **186 tons of Sb eq.**, or the equivalent **of 930 million tons of excavated soil**[14]. This also corresponds to **the metals and minerals contained in 62 million smartphones**.

The impact on freshwater ecotoxicity (CTUe) corresponds to **65,038,535,926 CTUe**. It is equivalent to the impact of producing approximately **1.1 billion bottles of shower gel annually**, or enough bottles to cover the consumption of the entire Swiss population for about 50 years[15].

Although it accounts for 14% of the total quantified impact, as shown on Figure 2, climate change remains a central environmental concern due to its systemic and long-term consequences. This impact corresponds to **almost 2 million tons of CO_2 eq.** Considering the consumption-based CO_2 emissions in Switzerland in 2023 are 122 million tons of CO_2[16], that means that **digital technologies are responsible for almost 2% of the total Swiss consumption-based CO_2 emissions.**

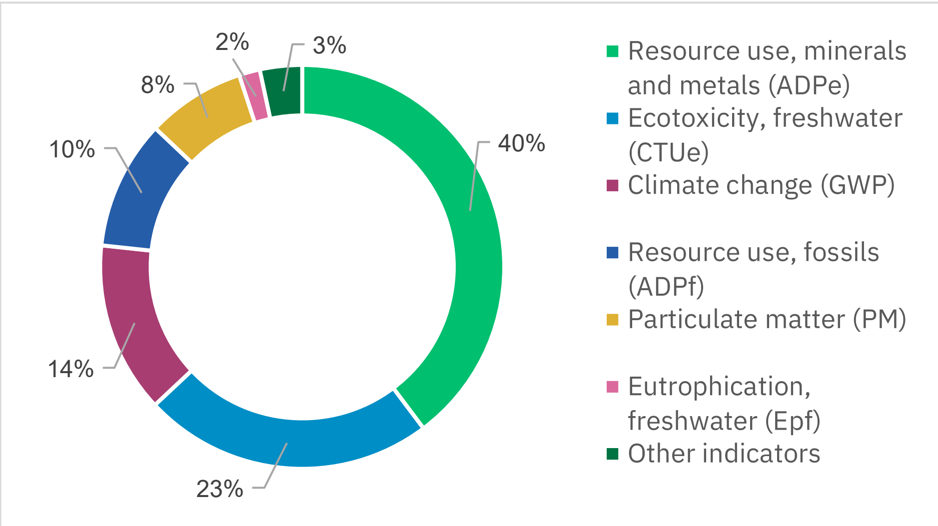

Figure 2- Contribution of the environmental indicators to the footprint

[14] Using a value of clarke of 2,00E-04 kg eq. Sb per ton of excavated soil.
[15] https://www.ecetoc.org/wp-content/uploads/2021/10/ECETOC-TR-127-Freshwater-ecotoxicity-as-an-impact-category-in-life-cycle-assessment.pdf and https://www.planetoscope.com/hygiene-beaute/435-consommation-de-shampoings-en-france.html
[16] https://ourworldindata.org/co2/country/switzerland#consumption-based-accounting-how-do-emissions-compare-when-we-adjust-for-trade

3.1.3 Environmental impacts at the individual scale

Environmental footprint results of ICT technologies per capita are presented.

Resource use, minerals and metals (ADPe)

20.7 g of Sb eq.

Equivalence: 7 smartphones bought per capita in a year

Climate Change (GWP)

221 kg of CO_2 eq.

Equivalence: 524km by car per capita in a year

Ecotoxicity, freshwater (CTUe)

7,224 CTUe

Equivalence: 127 bottles of shower gel per capita in a year

3.1.4 Comparisons to Planetary Boundaries

Planetary boundaries refer to critical ecological thresholds that define a safe operating space for humanity. These thresholds aim to quantify the limits within which global environmental systems can continue to function stably and sustainably. It is possible to compare the environmental footprint of digital technologies per capita to the planetary boundaries in order to evaluate whether it stays within globally sustainable levels.

Figure 3 illustrates the contribution of the impacts to the planetary limits. In 2024, digital technologies in Switzerland consume 22% of the annual per capita sustainable budget to stay below 1°C of global warming, the planetary limit for climate change. Similarly, it consumes 65% of the annual sustainable budget in terms of the use of mineral and metal resources, and almost 38% of the planetary sustainable budget in terms of freshwater ecotoxicity.

The data clearly demonstrate that while the ICT sector does not yet exceed any planetary boundaries per capita in Switzerland, it already consumes substantial portions of the safe operating space - particularly for mineral resource use, freshwater ecotoxicity, and climate change.

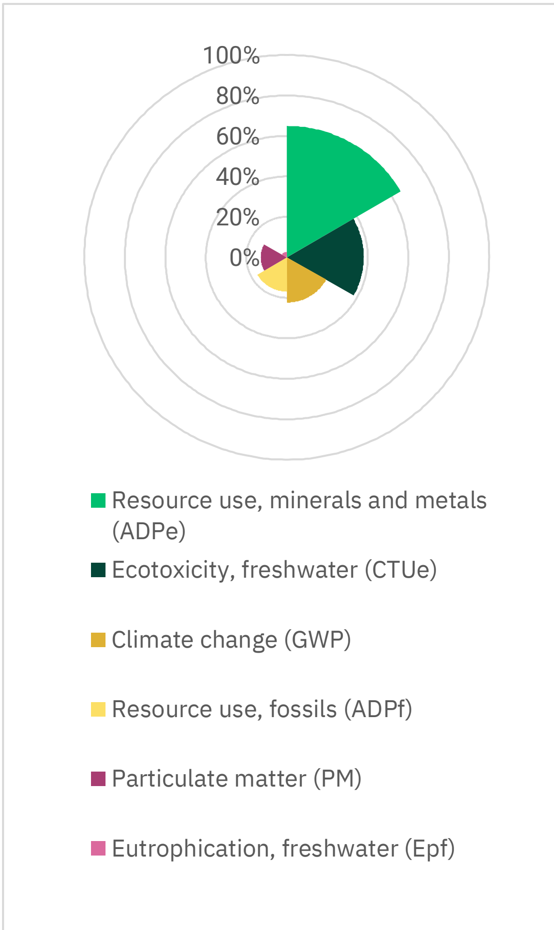

Figure 3- Planetary boundaries results

3.2 Repartition of the environmental impacts

3.2.1 Repartition of the results per Tier

As illustrated in Figure 4, **personal end-user terminals** represent the most significant share, accounting for **51%** of the impact on climate change. **Professional equipment** represents **25%** of the environmental footprint. However, the sizes of the populations concerned are not the same. There are about 9 million inhabitants whereas there are about 5 million employed individuals.

Overall, the **end-user terminal category regroups 76% of the total impact**. **Data centres contribute to 20%** of the total digital technologies' footprint on climate change. Finally, **telecommunications networks account for only 4%** of the total environmental impact. Despite their essential role in ensuring digital connectivity nationwide, their relative footprint remains modest.

This repartition on the climate change impact category is similar to the one for the other impact categories. One impact category stands out, freshwater eutrophication, for which data centres concentrate almost 50% of the total footprint. To better understand the distribution of these impacts, it is necessary to study it according to the life cycle, detailed in the next section.

3.2.2 Repartition of the results per life cycle stage

Figure 5 illustrates the environmental footprint repartition by life cycle stage. Overall, two key life cycle stages clearly emerge: manufacturing and usage.

The **predominance of the manufacturing phase** comes largely from the end-user equipment (Tier I), for which the extraction and transformation of raw materials generate high resource and energy demands. This is

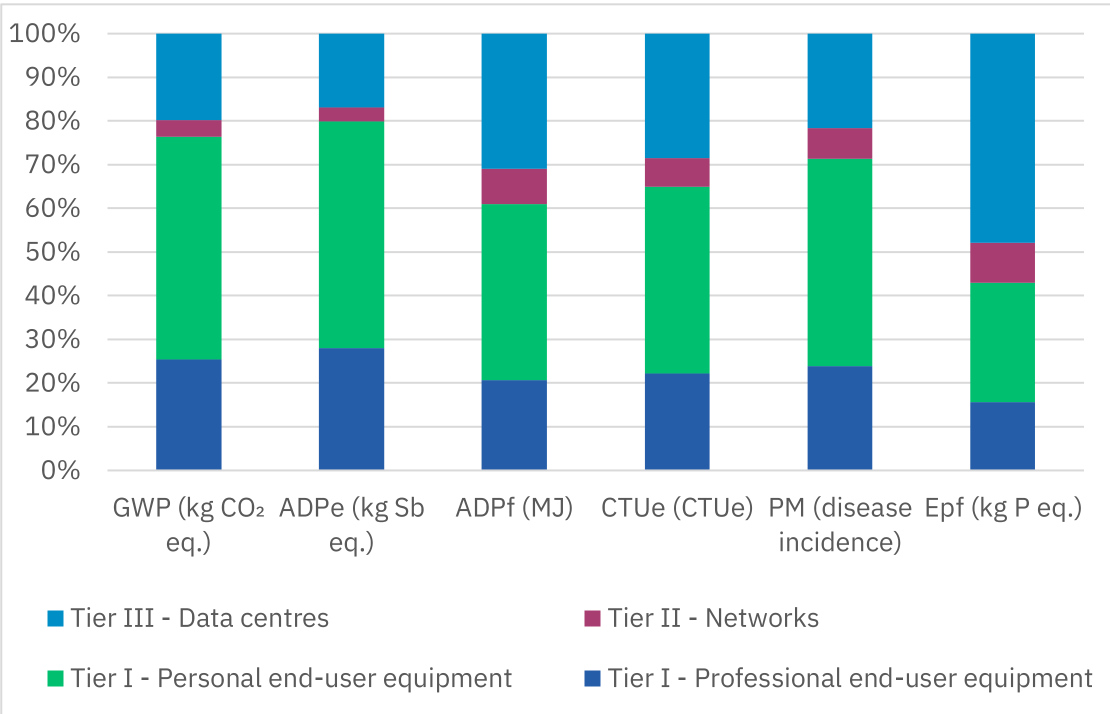

Figure 4- Global environmental footprint repartition by Tier

primarily attributed to the **high number of end-user devices** in circulation and their relatively **short lifespans**, compared to network and data centres equipment.

The **usage phase** follows, with impacts more evenly distributed between end-user equipment and data centres. This highlights the significant **electricity consumption** associated with **datacentres infrastructure**, despite its relatively small number of devices compared to end-user equipment. On the opposite end-user devices are very numerous but their individual electricity consumption is much lower.

The usage phase contributes less significantly to climate change impact category. Indeed, the electricity consumed is coming from an electricity mix that is heavily based on renewable energy sources (mainly hydropower)[17], which reduces the associated environmental impact. However, as the manufacturing of the devices and electronic components is mainly happening in South-East Asia, the electricity used during this stage has more impact and increases the impact of manufacturing.

The **usage phase** is the **dominant contributor for freshwater eutrophication**. These impacts are due to the **distribution of electricity** through the grid using **copper**. Soluble phosphate is added to sulfidic tailings generated during copper mining to alleviated acute phytotoxicity[18].

The **distribution and end-of-life phases** have **negligible environmental impacts**, except on freshwater ecotoxicity, as end-of-life, accounts for approximately 15% of the impact. This is due to the high sensitivity of this indicator to the leaking of toxic substances, such as heavy metals and persistent organic compounds, into the environment. This phenomenon is particularly relevant during the disposal of electronic equipment.

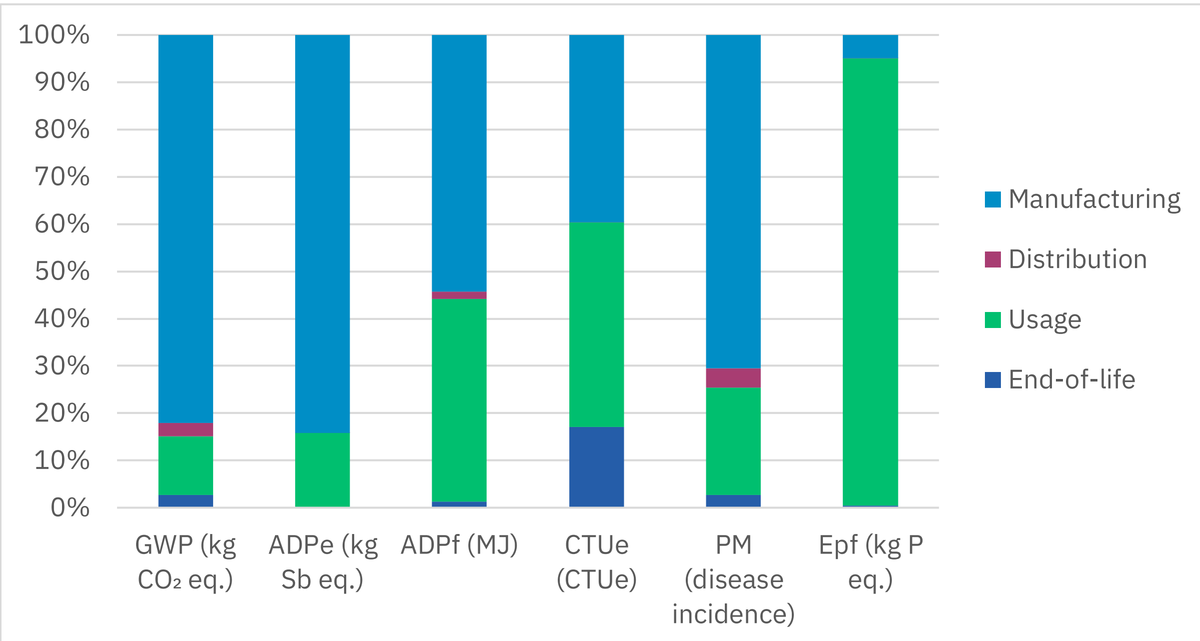

Figure 5- Global environmental footprint repartition by life cycle stage

[17] https://www.news.admin.ch/fr/nsb?id=97643

[18] https://www.sciencedirect.com/science/article/abs/pii/S0269749119304920#:~:text=As%20a%20result%2C%20it%20is%20hypothesized%20that,tailings%2C%20improving%20the%20success%20of%20tailings%20phytostabilization.

3.2.3 Focus on Tier I – End-user equipment

As a reminder, end-user equipment (Tier I) is categorised between personal and professional use. Figure 6 shows that **household ICT equipment** impacts in Switzerland are dominated by the environmental impacts of **smartphones** and **televisions**. Smartphones account for 25% of the climate change impacts (GWP) and TVs for 15%, making them the largest contributors. Screens (TVs and computer monitors) also represent 41% of abiotic resource depletion (ADPe) and 33% of eutrophication impacts. This mainly due to their large numbers.

Televisions and screens contribute significantly to the environmental footprint of digital equipment, particularly due to their size and energy consumption. Around 98% of the current stock consists of LCD screens, with an average diagonal size of 47 inches. Although OLED models-typically around 60 inches-are increasingly sold, they still represent a small fraction of the installed stock.

Laptops and desktops contribute 13% and 8% of GWP respectively, while smaller devices like modems, printers, and set-top boxes have more localized impacts, notably in eutrophication (e.g., 19% for modems) and particulate matter emissions (e.g., 11% for laptops and printers). In contrast, IoT devices, projectors, and landline phones have minimal impact (≤2% GWP each), though the rising number of IoT devices may increase their future footprint.

Figure 7 shows that concerning **professional end-user equipment**, **laptops** and **computer monitors** are the primary contributors to environmental impacts across most categories. Laptops stand out, accounting for

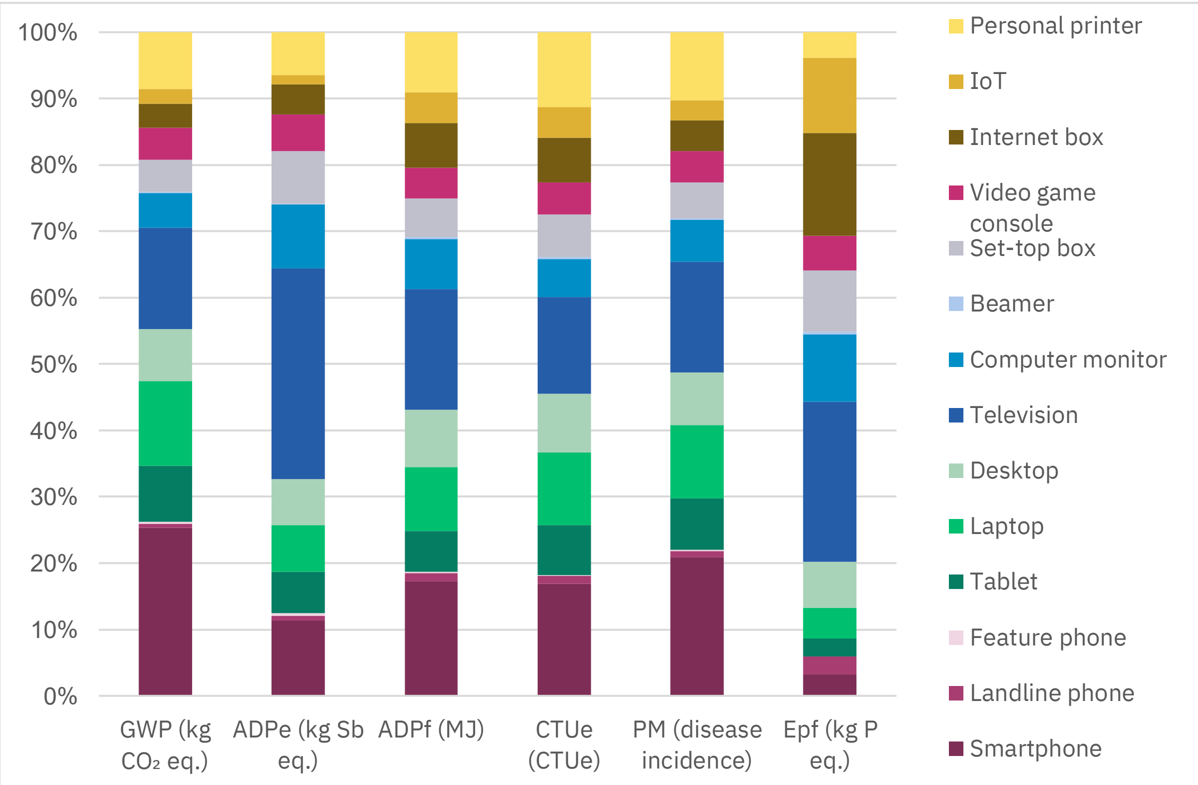

Figure 6- End-user equipment (Tier I) for personal use environmental footprint repartition by equipment category in Switzerland in 2024

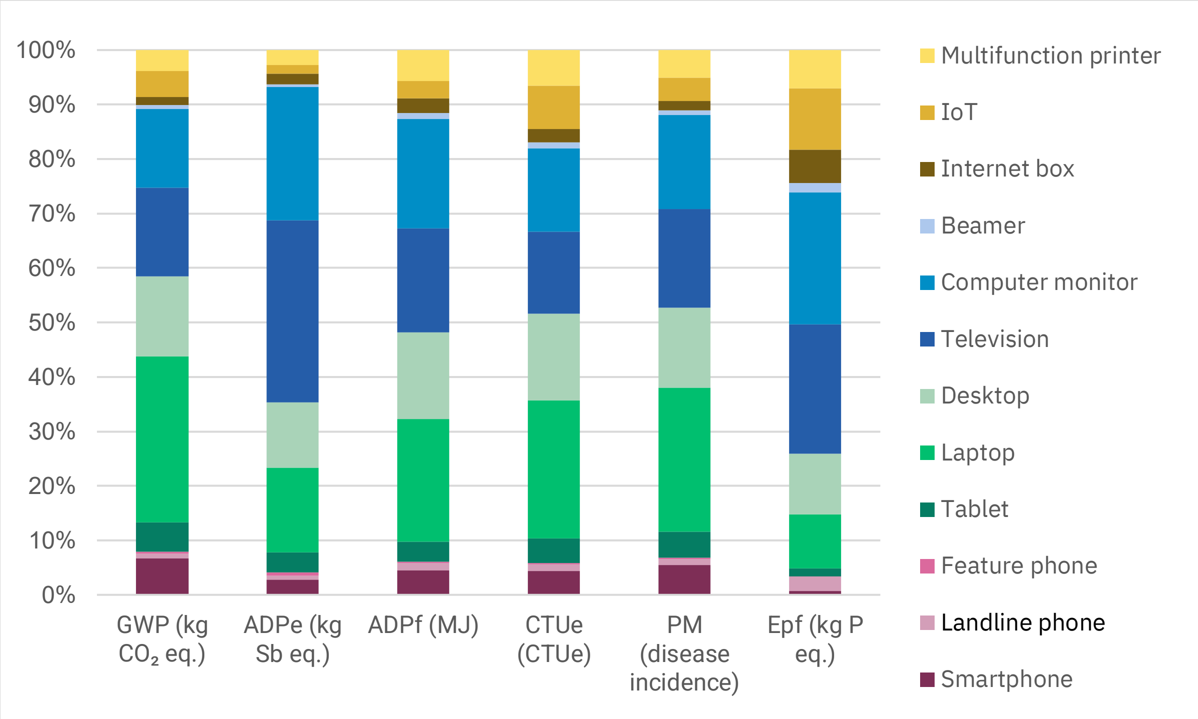

Figure 7- End-user equipment (Tier I) for professional use environmental footprint repartition by equipment category in Switzerland in 2024

27% of global warming potential (GWP), 21% of fossil resource use (ADPf), and 22% of human toxicity (CTUe). Computer monitors also have a significant environmental footprint, with the highest contributions to mineral resource depletion (39% of ADPe) and freshwater eutrophication (36% of Epf), as well as high impacts on GWP (18%) and particulate matter formation (22%). This is because they are now an indispensable part of employees' work tools, specifically in the service sector.

Smartphones follow as another major contributor, especially for GWP (18%) and particulate matter emissions (15%), highlighting their disproportionate environmental impacts given their small size. Desktops show a moderate but consistent contribution across all indicators, ranging from 15% to 19%. This is consistent with a shift in recent years towards the use of laptops instead of desktops, especially in companies.

3.2.4 Focus on Tier II – Networks

As seen in Figure 8, electricity use, especially for fixed networks, is the primary driver of environmental impacts in Tier II, reaching up to 56% of eutrophication and 43% of human toxicity impacts. Mobile electricity also plays a major role across all indicators (14 to 34%).

Among equipment, most of the impacts is also attributed to fixed networks. OCNs, coaxial cables and optic fibre stand out with significant contributions, particularly in global warming, resource use, and particulate matter formation. Concerning mobile network, amplifiers and passive antennas are the major contributors.

It appears that most impacts are attributed to fixed network, with 60% to 70% of the total Tier II footprint. This repartition is very different from what can be observed in other studies, such as the evaluation of the environmental footprint of internet service

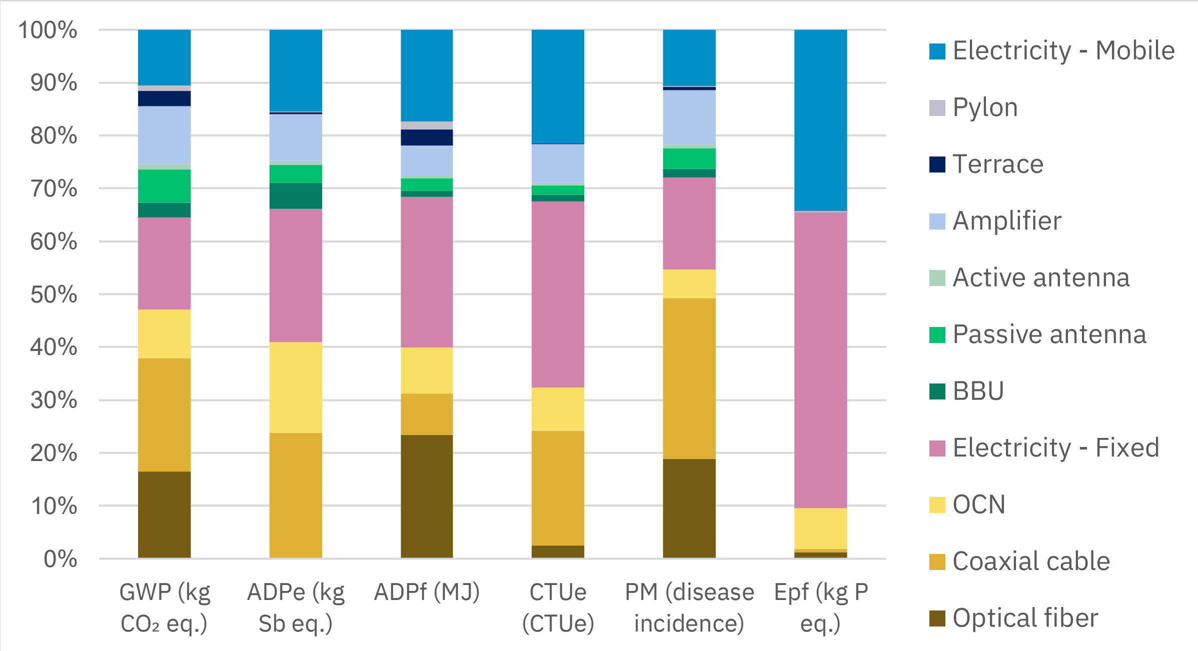

Figure 8- Telecommunication networks (Tier II) environmental footprint repartition by equipment category in Switzerland in 2024

provisioning in France[19]. In this study, the electricity consumption is more concentrated in the mobile network. The main hypothesis for this discrepancy is differences in the perimeter considered. It is possible that small data centres of internet service providers and PoPs (Points of Presence) are included whereas they are not in the other study.

3.2.5 Focus on Tier III – Data centres

Figure 9 shows the repartition of data centres environmental footprint between the various categories of equipment.

Electricity consumption (for ICT and non-ICT equipment) dominates most indicators, especially freshwater eutrophication (98% of total) and freshwater ecotoxicity (76% of total). Electricity consumption is separated into electricity for ICT equipment (servers, storage servers, switches) and for non-ICT equipment (cooling, electrical power supply). A ratio of 2.4 can be seen between non-ICT and ICT electricity (corresponding to a PUE (Power Usage Effectiveness) of 1.4).

The **ICT equipment** and their associated electricity consumption represent between 65% and 85% of the footprint. Servers and storage servers come second after electricity consumption. Servers are the largest contributor to global warming potential (43% of GWP footprint), driven by energy-intensive manufacturing processes and operational demands. In comparison, electricity consumption is 22% so twice less important. This repartition is quite different than what could be usually observed for servers. Indeed, as they are power intensive equipment, usage phase is generally the most impactful even for GWP indicator. In this study, Switzerland's electricity mix has a very low carbon impact: 34.6 g eq. CO_2/kWh from Ecoinvent.

[19] https://librairie.ademe.fr/industrie-et-production-durable/7111-evaluation-of-the-environmental-footprint-of-internet-service-provisioning-in-france.html

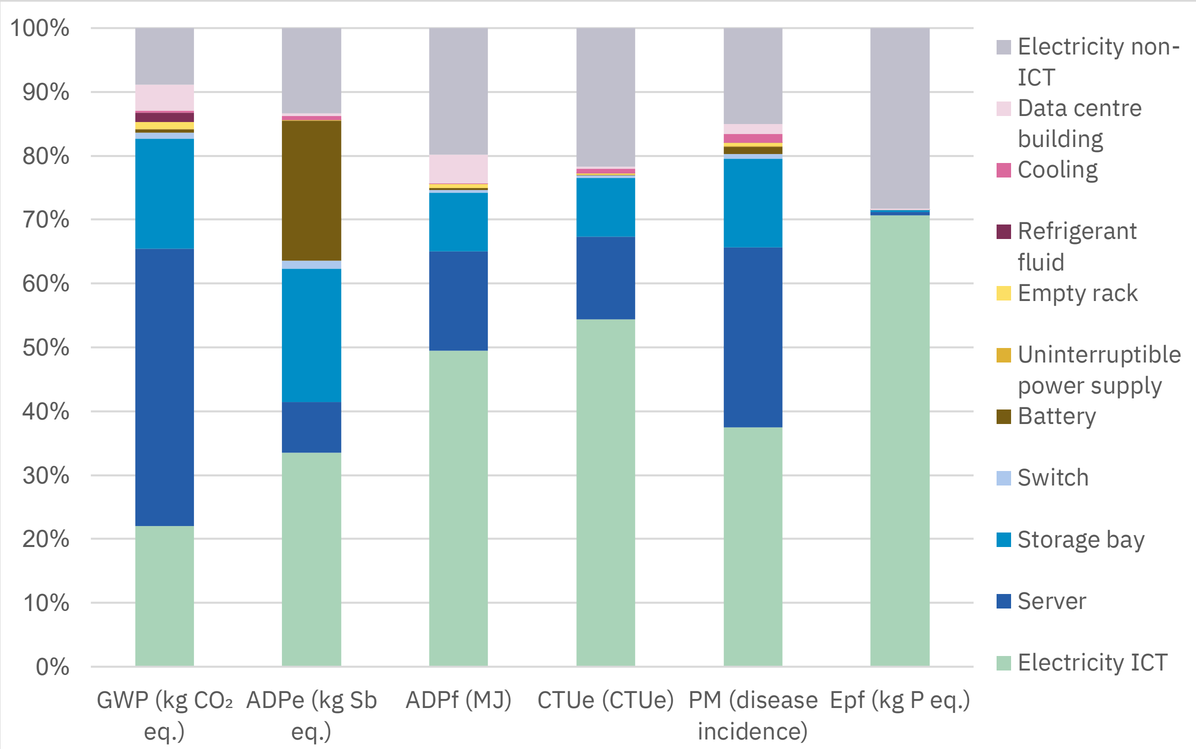

Figure 9- Data centres (Tier III) environmental footprint repartition by equipment category in Switzerland in 2024

Among all servers, **storage servers** represent about 50% of the total impact of servers. Mid-range servers are the second most impactful category due to their number. Their impact is 15 times higher than AI-dedicated servers. AI-dedicated servers are the third most impactful category of servers. This is due to their higher unitary impact (due to the presence of a GPU) and the fact that they are a bit more numerous than high-range servers.

The **technical environment** (building, cooling, electrical power supply and associated electricity consumption) **represents 15% to 35% of the data centres footprint**. The impacts are mainly concentrated in the electricity consumption. The ADPe environmental indicator is an exception as batteries account for the majority of the impacts (31%). This is because lead batteries need a considerable amount of minerals and metals for their manufacturing.

The repartition of the footprint between the life cycle stages shows similar pattern with Tier II. In the usage phase, the two fluxes are the electricity consumption and the refrigerant fluid consumption. Electricity consumption accounts for almost all of the impact, refrigerant fluid impact is almost negligible.

The rest of the impact is linked to manufacturing impact for ICT and non-ICT equipment. Distribution and end-of-life represent only a few percents of the total impact.

3.3 Projections in 2035

Projecting the environmental impacts of ICT up to 2035 is essential for anticipating future trends in digitalization, infrastructure development, and user behaviour. As the demand for digital services continues to rise, driven by new usages such as AI, IoT, and 5G, understanding the **long-term environmental**

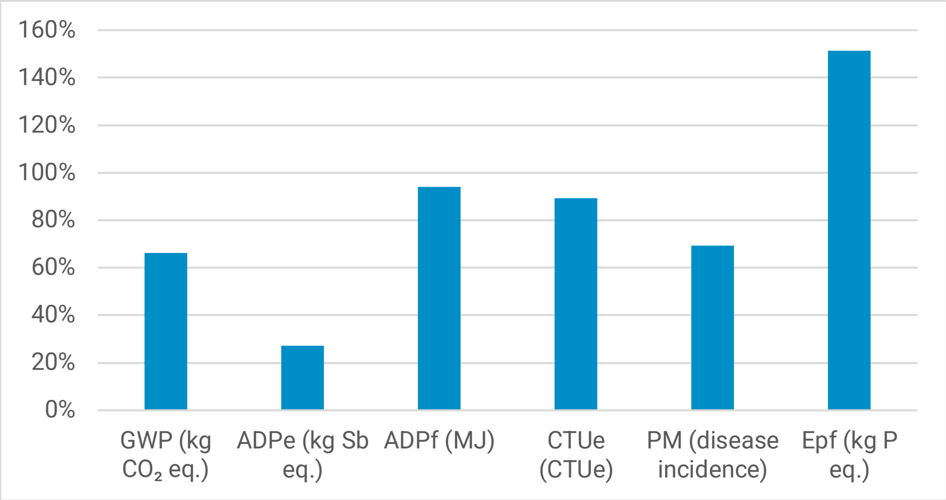

Figure 10- Increase percentage in the impact of digital technology in Switzerland between 2024 and 2035

trajectory allows policymakers, companies, and researchers to **identify critical impact areas, assess the effectiveness of mitigation strategies, and support the transition toward more sustainable digital systems**.

3.3.1 Results per capita

The projections in Figure 10 established for 2035 highlight a **significant increase in the environmental impacts** of digital technologies in Switzerland across all indicators. Compared to the baseline year 2024, every environmental impact category shows a substantial rise, reflecting both the expansion of digital infrastructures and the intensification of digital service usage.

One can note that ADPe is the environmental indicator with the smallest increase, 27% between 2024 and 2035. This can be explained because the main increase concerns data centres for which electricity consumption impacts are prominent compared to hardware impacts.

3.3.2 Planetary boundaries

When contextualized within the planetary boundaries' framework, the projected environmental impacts of ICT in Switzerland by 2035 raise significant concerns. It is illustrated in Figure 11. The most alarming trend appears in **resource use (minerals and**

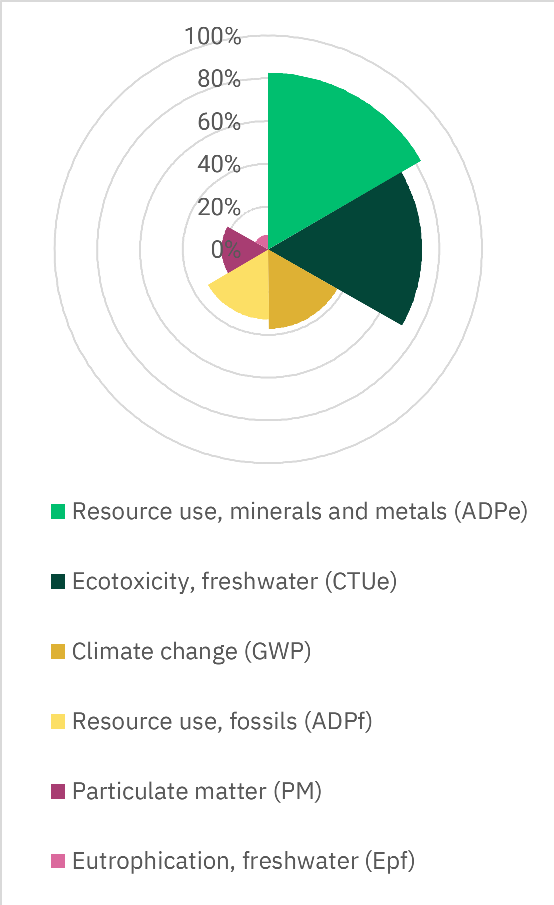

Figure 11- Planetary boundaries results in 2035

metals), **which jumps from 65% of the per capita planetary limit in 2024 to nearly 83% in 2035**. This indicates that, without intervention, the Swiss digital sector alone could consume a disproportionate share of the yearly planetary budget of the country's inhabitants. Freshwater ecotoxicity also approaches a critical threshold, rising from 39% to 72% of the per capita planetary limit.

Other indicators, though less prominent, show similarly concerning trends: climate change rises from 22% to 37%, fossil resource use increases from 17% to 33%, and fine particulate emissions rise from 13% to 22%, reflecting the growing resource demands and production intensities of digital infrastructure.

Overall, this planetary boundary comparison reveals that the environmental footprint of ICT in Switzerland is on a **trajectory that is incompatible with long-term global sustainability goals**, particularly in terms of material use and toxic emissions. It strengthens the case for targeted actions such as equipment circularity and a more restrained approach to digital growth.

4. Recommendations

After quantitatively studying the environmental impacts of digital technology in Switzerland between 2024 and 2035, it is necessary to identify the structural elements of the digital footprint. This will then enable us to identify the most appropriate actions and best practices for reducing this environmental footprint. That is the objective of this section.

4.1 Global objectives

Digital technologies have become integral to modern life in Switzerland, offering numerous benefits across various sectors. However, we demonstrate in this study that their environmental impact is substantial and growing. Notably, in 2024, a significant portion of this impact arises from end-user devices, such as smartphones and televisions. The manufacturing phase of these devices is particularly resource-intensive, accounting for a substantial share of the footprint.

Moreover, the results also show that the environmental impact of data centres is likely to increase significantly in the coming years, such that data centres will become the Tier with the greatest impact around 2035. Finally, telecommunications networks appear to have a moderate impact, accounting for no more than 10% of the total footprint. Though the uncertainty of the results for this Tier is very high and the environmental impacts are likely to be underestimated.

Despite the substantial impact associated with end-user equipment in 2024, **responsibility for mitigating the environmental impacts does not rest solely with individual consumers**. **Manufacturers, policymakers**, and **organizations** must play crucial roles in shaping sustainable practices and policies. For example, the design choices made by manufacturers can significantly influence a device's durability and reparability, while policymakers can implement regulations that promote both sustainable designs and production, as well as consumption habits.

In addressing the environmental challenges posed by digital technologies, prioritizing **effective and attainable actions** is essential. The three main objectives around which the recommendations are structured are the following:

- **Objective n°1: Decrease the need for manufacturing new devices**: Avoiding manufacturing new equipment whenever it is possible by extending the lifespan of devices currently in use and reducing their number;
- **Objective n°2: Design and manufacture more efficient equipment and infrastructures**: Manufacture less resource-intensive equipment and infrastructures, by putting into practice sobriety and circularity approaches;
- **Objective n°3: Arbitrating digital usage**: Critically assessing and moderating the use of digital technologies to ensure they meet genuine needs without excess.

4.2 Recommendations per objective, tier and stakeholder

To reduce the environmental impact of digital technologies in Switzerland, it's important to examine end-user devices, telecommunication networks, and data centres, as each contributes differently to the overall footprint. Analysing their life cycles and usage patterns reveals opportunities to enhance sustainability. The approach must involve all stakeholders (public authorities, businesses, organizations, and citizens) each with specific roles in driving change. Tailored recommendations for each group can foster collective action toward a more sustainable digital sector in Switzerland.

4.2.1 Objective 1: Decrease the need for manufacturing new devices

<table>
<tr><th></th><th>Public authorities</th><th>Citizens</th><th>Businesses and organisations</th></tr>
<tr><th>Tier I</th><td>• Promote practices that prolong the lifespan of devices, such as regular maintenance, repairs, availability of spare part and software updates, to avoid programmed obsolescence.</td><td>• Buy equipment that are second-hand, with high reparability index or relevant label (e.g. TCO, EPEAT), along with warranty extensions.
• Protect, repair, take care of the equipment all along the lifespan.
• Give or sell unused equipment if they are reusable. Otherwise, recycle them, in order to give a second life to the equipment, its components or material.</td><td>• Mutualise equipment between multiple users. Encouraging the use of fewer devices per individual, and advocating for shared or multifunctional equipment.
• Share equipment for multiple uses: BYOD (Bring Your Own Device) approach to combine personal and professional use.
• Reduce the number and sizes of screens.</td></tr>
<tr><th>Tier II</th><td colspan="2">• Optimise the number of equipment: coordinate inter-operator collaborations to avoid useless redundancy on network infrastructures and share equipment and infrastructure, particularly in less densely populated areas.</td><td></td></tr>
<tr><th>Tier III</th><td></td><td></td><td></td></tr>
<tr><th>All tiers</th><td>• Enhance e-waste collection infrastructure and recycling programs to ensure the proper disposal and recovery of valuable materials from obsolete electronic devices.
• Ensure the framework conditions that will enable a longer service life.</td><td></td><td>• Maintain transparency concerning environmental impacts of digital infrastructures, equipment and services.</td></tr>
</table>

4.2.2 Objective 2: Design and manufacture more efficient equipment and infrastructure

	Public authorities	Citizens	Businesses and organisations
Tier I	• Create and democratize standards and labels for more energy efficient devices. • Offer systematic eco-design training in engineering schools.		• Apply eco-design principles at the hardware design stage, for more robust and reparable devices • Design end-user equipment that are less resource-intensive: consuming less electricity, recyclable, using recycled material, etc.
Tier II			• Enhance energy efficiency of new network equipment. • Implement smart network management systems to optimize energy usage dynamically.
Tier III	• Regulate the development of new data centres by prioritising energy-efficient solutions, such as heat reuse.		• Improve energy efficiency of new infrastructure, therefore enhancing the PUE. • Improve energy efficiency of new ICT equipment. • Incentivize the use of environmentally optimized data centres powered by renewable energy and located within Swiss or European jurisdictions
All tiers	• Ensure the framework conditions that will enable a better energy efficiency		

4.2.3 Objective 3: Arbitrating digital usage

	Public authorities	Citizens	Businesses and organisations
Tier I			
Tier II			
Tier III	• Regulate and slow down the spread of new usages, particularly the use of AI.		
All tiers	• Inform and consult citizens regarding the environmental consequences of digital technologies, promoting a collective approach to sustainable digital transitions. • Implement clear environmental standards and usage limitations, particularly in high-impact domains such as artificial intelligence, to mitigate environmental impacts.	• Reflect on personal digital consumption patterns and seek information on the environmental implications of digital usage.	• Shift towards business models that reduce dependency on the continuous production and sale of new electronic devices
All tiers	• Question the environmental cost and expected benefit of new technologies such as 6G, connected watches, AI, etc.		

5. Conclusion

5.1 Key findings

This study provides a detailed examination of the environmental impacts of the **Information and Communication Technology (ICT) sector in Switzerland** and reveals a reality that is often underestimated: digital technologies have a **significant environmental impact**. Far from being immaterial, the digital sector is heavily dependent on physical resources and produces significant emissions and waste.

The first observation is that **Switzerland is highly digitalised**. In 2024, 99% of the population regularly accesses the internet and each inhabitant owns an average of 6 digital devices. Furthermore, ICT infrastructures consume 12% of Switzerland's electricity consumption.

ICT consumes substantial portions of the safe operating space delimited by the planetary boundaries, particularly for mineral resource use, freshwater ecotoxicity and climate change. Its **footprint is increasing rapidly**, with expected increases ranging from 27% to 151% **until 2035**, depending on the environmental categories. These trends are due to the increase of the population and the growth of new usages (generative AI, blockchain, virtual reality, etc.).

Moreover, this study highlights the **critical role of material resource use**, particularly rare earth elements and strategic metals, in the environmental burden of digital technologies. Digital technologies consume 65% of the annual sustainable budget defined by planetary boundaries in terms of the use of mineral and metal resources, and is expected to increase to 83% by 2035. This is particularly concerning given the **rising demand for electronics**.

Another insight is that **end-user equipment** is **the main driver of environmental impacts in Switzerland in 2024**. However, the trends until 2035 show that data centres and networks footprints are increasing and **data centres are going to concentre the most impacts by 2035**.

All these observations underscore the need for **targeted mitigation strategies** as well as a broader governance framework to ensure the sustainability of the digital transformation. As a highly connected and technologically advanced nation, Switzerland's role is pivotal, both in setting national policies and in influencing global digital sustainability efforts.

Responsibility for mitigating the environmental impacts must not rest solely with individual consumers. Manufacturers, policymakers, and organizations must play crucial roles in shaping sustainable practices and policies. The three main objectives that structure the recommendations are:

- **Decrease the need for manufacturing new devices;**
- **Design and manufacture more efficient equipment and infrastructures;**
- **Arbitrating digital usage.**

In summary, **digital sobriety**, doing less and doing better, must be at the heart of Switzerland's digital policy. Technical efficiency alone will not be sufficient. A sustainable ICT future will depend on managing demand, extending product lifespans, and redesigning digital services to serve societal needs without overshooting planetary boundaries.

5.2 Limits of the study

While the results, conclusions, and recommendations presented in this study provide a robust and structured understanding of the environmental impacts of the ICT sector in Switzerland, they must be considered in light of certain **methodological and data-related limitations**.

These constraints do not call into question the overall validity of the findings but rather clarify the conditions under which they should be interpreted. Addressing these aspects transparently is essential to support a critical reading of the study and to guide improvements in future assessments.

5.2.1 Limitations due to study scope

Several limitations related to the scope of the analysis must be acknowledged, as they may lead to a slight underestimation of the impacts:

- Some **equipment** and **infrastructure** categories were **not taken into account** due to insufficient or unreliable data, to ensure the methodological consistency of the analysis;
- Not all life cycle stages were fully considered. **Maintenance, refurbishment** and upgrades were **omitted**, despite their growing importance in circular economy models;
- **Indirect impacts**, such as employee commuting and infrastructure overheads, were also excluded.

5.2.2 Limitations associated with life cycle inventory and data collection

The study faces limitations linked to the life cycle inventory (LCI) data and modelling assumptions. Key uncertainties include:

- **Generalized estimates** are used for technical specifications, energy use, and product lifespans, and may not fully reflect the variety of devices on the Swiss market;
- **Projections to 2035** rely on historical trends and linear assumptions, which may overlook disruptive changes or policy shifts, making these forecasts plausible scenarios rather than precise predictions;
- Use of an **annual average Swiss electricity mix** that may not capture seasonal variations;
- Additional challenges include limited data on IoT devices, unquantified impacts from international data exchanges.

5.2.3 Possible improvements

While this study marks a strong starting point in assessing the environmental impact of Switzerland's ICT sector, future analyses could provide a more complete and nuanced understanding of the sector's total footprint, such as:

- Expand the scope to include overlooked technologies (like certain IoT devices and industrial systems);
- Apply more granular distinctions between personal and professional infrastructures and devices;
- Apply a more dynamic approach for projected impacts, that reflect evolving technologies and behaviours with time.

This will allow to **increase the accuracy and policy relevance of future assessments**.

6. Thanks

We would like to offer our sincerest thanks to everyone who contributed to this study.

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